International Journal of Electrical and Computing Engineering
Vol. 1, Issue. 2, December – 2014 *ISSN (Online): 2349-8218*

Sensorless Fuzzy Logic Speed Control of Brushless DC Motor using Hysteresis Comparator

[1]**Nandhini.S,** [2]**Adhavan.B,** [1]PG Scholar, [2]Associate Professor, Department of EEE,
Sri Ramakrishna Engineering College, Coimbatore, INDIA. snandhini454@gmail.com,adhav14@yahoo.com

Abstract

Recently, Brushless Direct Current (BLDC) Motors are rapidly gaining popularity because of its high efficiency, high starting torque, compact size and long operating life. They are mostly used in industries such as automotive, aerospace, consumer industrial automation and instrumentation. This paper deals with sensor less speed control of BLDC Motor using Hysteresis comparator. Hysteresis comparator is used to compensate the phase delay of back-EMFs and also prevent multiple output transitions from noise or ripple in the terminal voltages. This approach is based on back-EMF terminal voltage sensing method. Fuzzy Logic Controller is used in order to enhance its robustness and reliability. The design analysis and simulation of proposed system is done using MATLAB version 2010a and the simulation results are discussed.

I.INTRODUCTION

Brushless DC motors were developed from conventional brushed DC motors with the availability of solid state power semiconductors. As the name indicates, BLDC motors do not use brushes for commutation. They have many advantages over brushed DC motors. BLDC motors can be made smaller and lighter than a brushed type with same power output, making it suitable for applications. Some of its advantages over brushed DC motors are: high dynamic response, noiseless operation, high speed ranges, high efficiency and long operating life.

BLDC motor types are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Automotive, Appliances, Aerospace, Medical, Industrial Automation Equipment and Instrumentation. Also the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors. In order to obtain ripple-free instantaneous torque of the BLDC motor, the rotor position information for stator current commutation must be known, which can be obtained using hall sensors mounted on the rotor. This results in a high costs as well as poor reliability. To cope with aforementioned restriction, many sensorless algorithms have been considered as a potential solution.

Most sensorless techniques are based on back-EMF estimation method also called as terminal voltage estimation method [1]. Sensorless control technique is proposed and the zero-crossing of the back-EMF measured from the stator winding is detected. Commutation points can be estimated by shifting 30° from the zero crossing of the back-EMFs [2]. The performance of the sensorless drive is sensitive to the phase delay of low-pass filter. This phase delay is compensated using phase shifters [3], [4]. Rotor position information is given by hall sensors. But in sensorless technique, the position information can be extracted by integrating the back-EMF of the silent phase but has an error accumulation problem at low speed [5]. The effect of the free-wheel diode conduction is removed and an improved sensorless controller is suggested [6]. But here, access to motor’s neutral point is required, which will increase the overall cost.

Most technique uses zero crossing point method of three-phase line-to-line voltages [7], [8]. This commutation signals can be obtained without any phase shifter and multiple output transitions may occur from high frequency ripple or noises. The zero crossing of back-EMF for generating proper commutation control is calculated. This is done by sampling the floating phase voltage without using sensors [9], [10].

The drawbacks of aforementioned sensorless techniques are restricted in some applications which require good reliability and high starting torque. In this paper, sensorless control technique is proposed based on hysteresis comparator. This hysteresis comparator is used to compensate the phase delay. It also prevents multiple output transitions from noise in the terminal voltages. The proposed work is able to improve the performance and reliability for the sensorless BLDC motor drive system.

II. SENSORLESS CONTROL TECHNIQUES

Brushless DC motor drives require rotor position information for proper operation. Position sensors are

usually used to provide the position information for the driver. However, in sensorless drives, position sensors are not used. The position information is obtained indirectly without using any sensors. This sensorless technique can be done with position sensing using back-EMF of the motor and position approximation using terminal voltage, current and motor parameters. Many sensorless techniques are based on the back-EMF of the motor. Generally, these techniques are used for Brushless DC machines with trapezoidal back-EMF. This back-EMF sensing methods can be classified into two types- Direct back-EMF sensing method and Indirect back-EMF sensing method.

Since filtering introduces commutation delay at high speeds and attenuation causes reduction in signal sensitivity at low speeds, the speed range is limited in direct back-EMF sensing methods. In order to reduce high frequency noise due to the PWM switching, the indirect back-EMF sensing methods are used. This method can be classified into- back-EMF integration, third harmonic voltage integration, free-wheeling diode conduction or terminal current sensing, flux integration method and observer method.

III. SENSORLESS CONTROL USING HYSTERESIS COMPARATOR

Drawbacks of aforementioned sensorless techniques are limited for some applications which require good reliability, wide speed range, fast startup and high starting torque. To satisfy these requirements, this paper presents a sensorless control based on hysteresis comparator of terminal voltage. Figure.1 shows the block diagram of a proposed system.

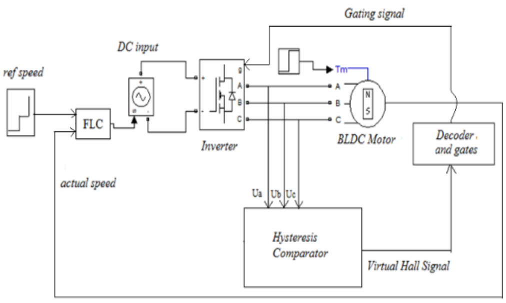

Fig.1 Block diagram of proposed system

This block diagram consists of a sensorless control technique with hysteresis comparator. The hysteresis comparator is used to compensate for the phase delay and also to prevent multiple output transitions from noise or ripple in the terminal voltages. It is able to improve both the performance and reliability for the sensorless BLDC motor drive system. Hysteresis comparators are bistable circuits. It is implemented by applying a positive feedback to any of the input terminal of the comparator. At a certain moment only one threshold is said to be active. Hysteresis comparators are also called as Schmitt trigger. This hysteresis comparator can be classified into two types namely, Inverting Hysteresis and Non-inverting Hysteresis. The terminal voltage from the BLDC motor is taken and it is compared. The compared voltage values are given to the hysteresis block. Here in MATLAB/Simulink, hysteresis block is designed using relay as hysteresis and its upper and lower band values are chosen such that, the terminal voltage values are band limited. Therefore, the waveform of the terminal voltage is nearly same as that of the back-EMF. The terminal voltages can be used to detect the commutation points of the Brushless DC motor instead of the back-EMF at the proposed sensorless control. Thus virtual hall signals are produced. These signals are given to the decoder circuit where gating pulses are produced. This gating pulse is given to the inverter unit often called as electronic commutators.

IV. FUZZY LOGIC CONTROLLER

The speed of the BLDC drive can be simulated using the Fuzzy logic controller. The Fuzzy logic system plays a central role in the controlling of linear systems and in industrial applications where the control and automation plays a vital role. Fuzzification permits to convert inputs into fuzzy variables by using membership functions. Each input and output has five sets associated with five linguistic values: Negative Big (NB), Negative Small (NS), Zero Error (ZE), Positive Small (PS) and Positive Big (PB) as shown in Table.1.

Table.1 Fuzzy Rule-based matrix

AS,RS	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PB	PB
PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PB	PB	PB

The Actual Speed and Reference Speed are compared and both are given as input to the fuzzy controller. Output is taken from the fuzzy. The inputs and output are given as below. Each input and output has five sets associated with five linguistic values as given in the Table.1. The linguistic value of input1 is given in Figure.2, input2 is given in Figure.3 and output values are given in Figure.4 respectively as given below.

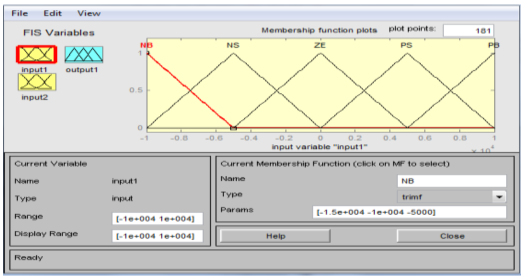

Fig.2 Input1 to fuzzy

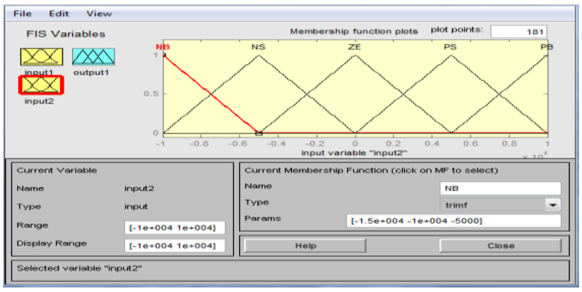

Fig.3 Input2 to fuzzy

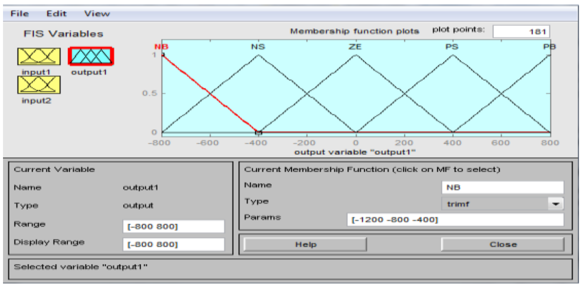

Fig.4 Output from fuzzy

In the inference mechanism, the value of fuzzy output is determined using a rule base. A typical rule is explained as:

IF (condition 1) AND (condition 2) THEN (conclusion)

The approximation law of the fuzzy function approximator contains 25 rules. The inference method which has been chosen is the max-min method that was proposed by Mamdani type.

The output of the inference mechanism is fuzzy output variable. The fuzzy function approximator must convert its internal fuzzy output variables into crisp values so that the actual system can use these variables. This process of converting the fuzzy output into real value output is called as Defuzzification. Centroid method of de-fuzzification is used because it can be easily implemented and requires less computational time

V. SIMULATION RESULTS

The proposed system using hysteresis comparator is implemented in MATLAB/Simulink R2010a. The simulation results were being discussed.

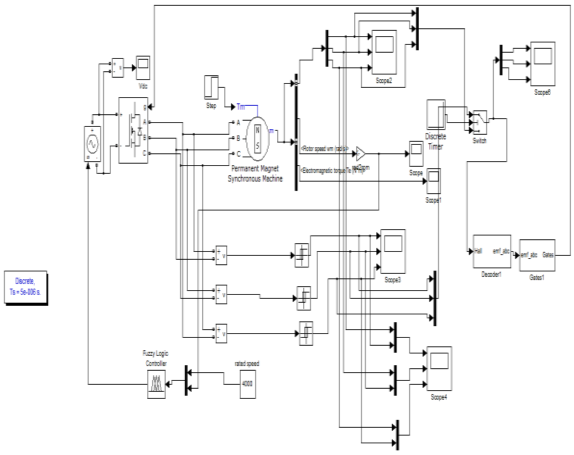

Fig.5 Simulink model of Sensorless BLDC motor using Fuzzy logic controller

The virtual hall signal output is shown as given below in Figure.6

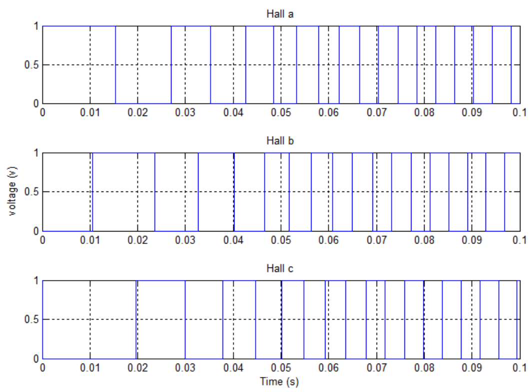

Fig.6 output waveform of hall signal from BLDC motor

The speed of the BLDC motor is controlled using fuzzy logic controller. Here the output response for given speed is shown in Figure.7

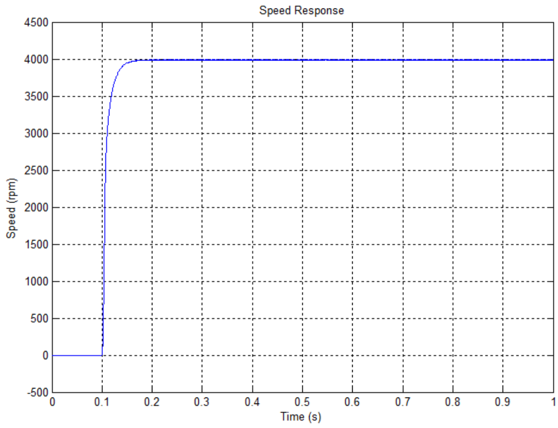

Fig.7

Speed response of BLDC motor

From the above diagram, the speed response of BLDC motor for given speed with time is observed and it is clear that the motor can also be controlled for different speeds.

VI. CONCLUSION

Sensorless Fuzzy Logic Speed Control of BLDC motor drive using Hysteresis Comparator has been simulated using MATLAB/SIMULINK and its performance for given speed is observed. The Hysteresis comparator is used to prevent multiple output transitions from noise or ripple in the terminal voltage. The results obtained from sensorless speed control of BLDC motor demonstrate that the system is less cost compared to sensored control and also good speed response is obtained. The results which are obtained confirm the effectiveness of the proposed system under various speed ranges. This makes the motor suitable in applications such as fuel pump, robotics, industrial automation, etc. The proposed Fuzzy Logic based speed control of BLDC motor drive with hysteresis comparator is more robust, efficient and easy to implement.

VII. FUTURE SCOPE

In future, the proposed work can be implemented in hardware and the results can be enriched with betterment in output. This can also be implemented using Artificial Neural Network (ANN) which results in better performance in this sensorless control area. This method will be more cost effective and have good dynamic response.

VIII. REFERENCES

[1] Tae-Won Chun , Quang-Vinh Tran, Hong-Hee Lee, Heung-Geun Kim, "Sensorless Control of BLDC Motor Drive for an Automotive Fuel Pump Using a Hysteresis Comparator", IEEE Trans. Power Electron., vol. 29, no. 3, Mar 2014.

[2] J. Fang, X. Zhou and G. liu, "Precise accelerated torque control for small inductance Brushless DC Motor", IEEE Trans. Power Electron., vol.28, no. 3, Mar 2013.

[3] N. Matsui, "Sensorless PM Brushless DC Motor Drives", IEEE Trans. Ind. Electron., vol. 43, no. 2, Apr 1996.

[4] K.Y. Cheng and Y.Y. Tzou, "Design of a sensorless commutation IC for BLDC motors", IEEE Trans. Power Electron., vol.18, no. 6, Nov 2003.

[5] D.H. Jung and I.J. Ha, "Low-cost sensorless control of Brushless DC Motors using a frequency-independent phase shifter", IEEE Trans. Power Electron., vol.15, no. 4, July 2000.

[6] M. Fraq and D. Ishak, "A new scheme sensorless control of BLDC motor using software PLL and third-harmonic back-emf", in Proc. IEEE Symp. Ind. Electron. Appl., 2009.

[7] J.X. Shen and S. Iwasaki, "Sensorless control of ultrahigh speed PM Brushless motor using PLL and third-harmonic back-emf", IEEE Trans. Ind. Electron., vol. 53, no. 2, Apr 2006.

[8] S. Tara Kalyani, Syfullah khan Md, "Simulation of sensorless operation of BLDC motor based on the zero-cross detection from the line voltage" , IJAREEIE, vol. 2, Dec 2013.

[9] A. Halvaei, A. Vahedi and H. Moghbelli, "A novel position sensorless control for a four-switch, Brushless motor drive without phase shifter", IEEE Trans. Power Electron., vol. 23, no. 6, Nov 2008.